

# A study of colliding plasma processes for elements of different mass

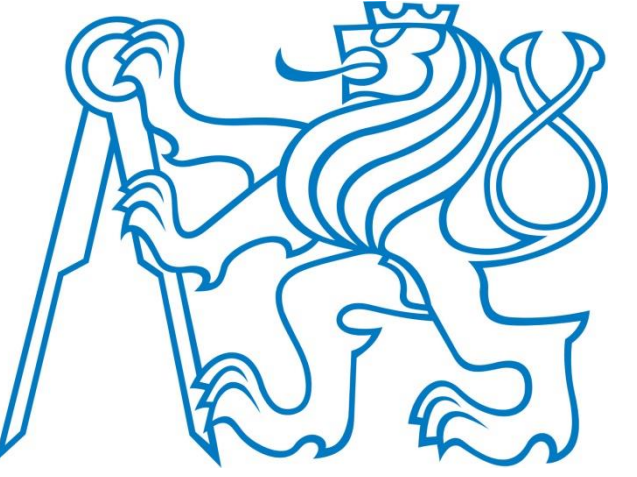


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## Abstract

Reheating of a Nd:YAG produced plasma with a CO<sub>2</sub> laser pulse has been shown to increase the conversion efficiency of laser radiation into 13.5 nm radiation, which is relevant to source development for next generation lithography. One proposed plasma for reheating was a stagnation layer formed between two colliding laser produced plasmas [1]. Properties of the stagnation layer, such as time of formation, duration and shape evolution, can be controlled so that the coupling of the reheating pulse into the plasma is optimized.

In this work we study differences in stagnation layer evolution for three elements, Si, Sn and Pb, investigated with iCCD images of optical emission from the plasma. Knowledge of how the mass of the colliding plasma particles affects the formation and properties of the stagnation layer, may facilitate better coupling of the reheating laser pulse to the plasma.

## Experimental setup

Plasma was created using a Continuum Surelite III Nd:YAG laser, with 950 mJ energy in 7 ns per pulse. Laser pulse was split in half using a 2 ° wedge prism before the vacuum chamber. Inside the chamber the 130 mm focusing lens was mounted on a moving stage, while target was mounted on an x-y-z stage. Images were captured with a gated iCCD Hamamatsu camera (C1764-03) through a visible light filter, and timing was controlled by a delay generator (Stanford DG645).

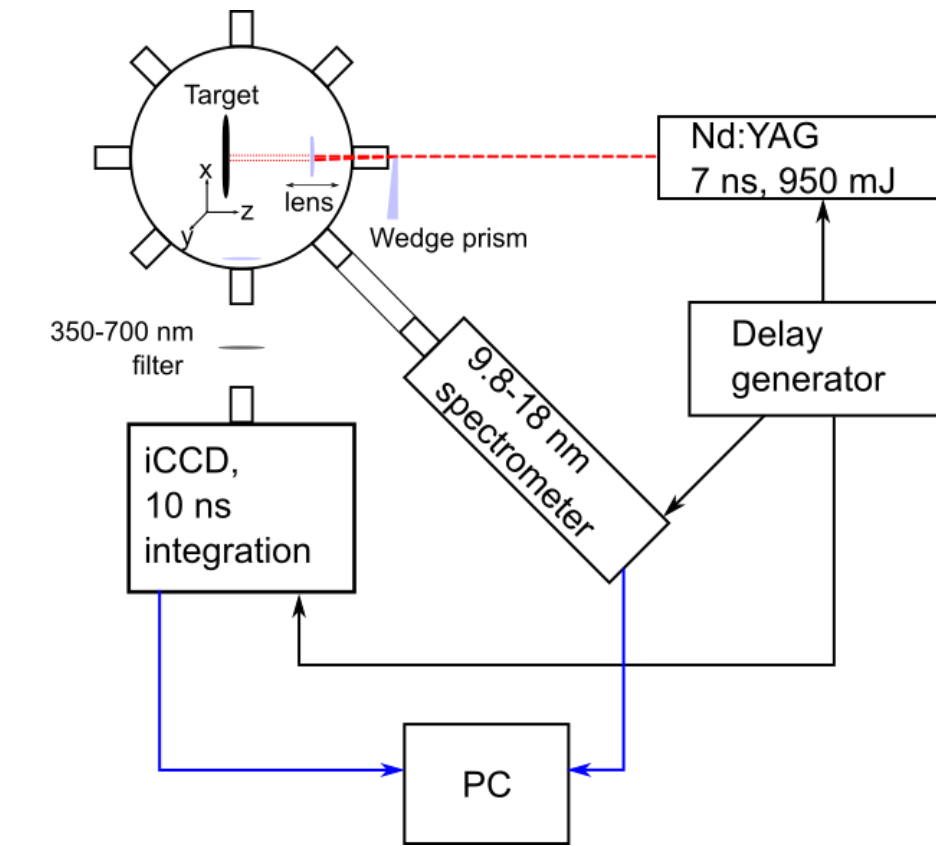


Figure 1. Experimental setup scheme

Sn colliding plasma, 10 ns integration, 250 ns after laser field

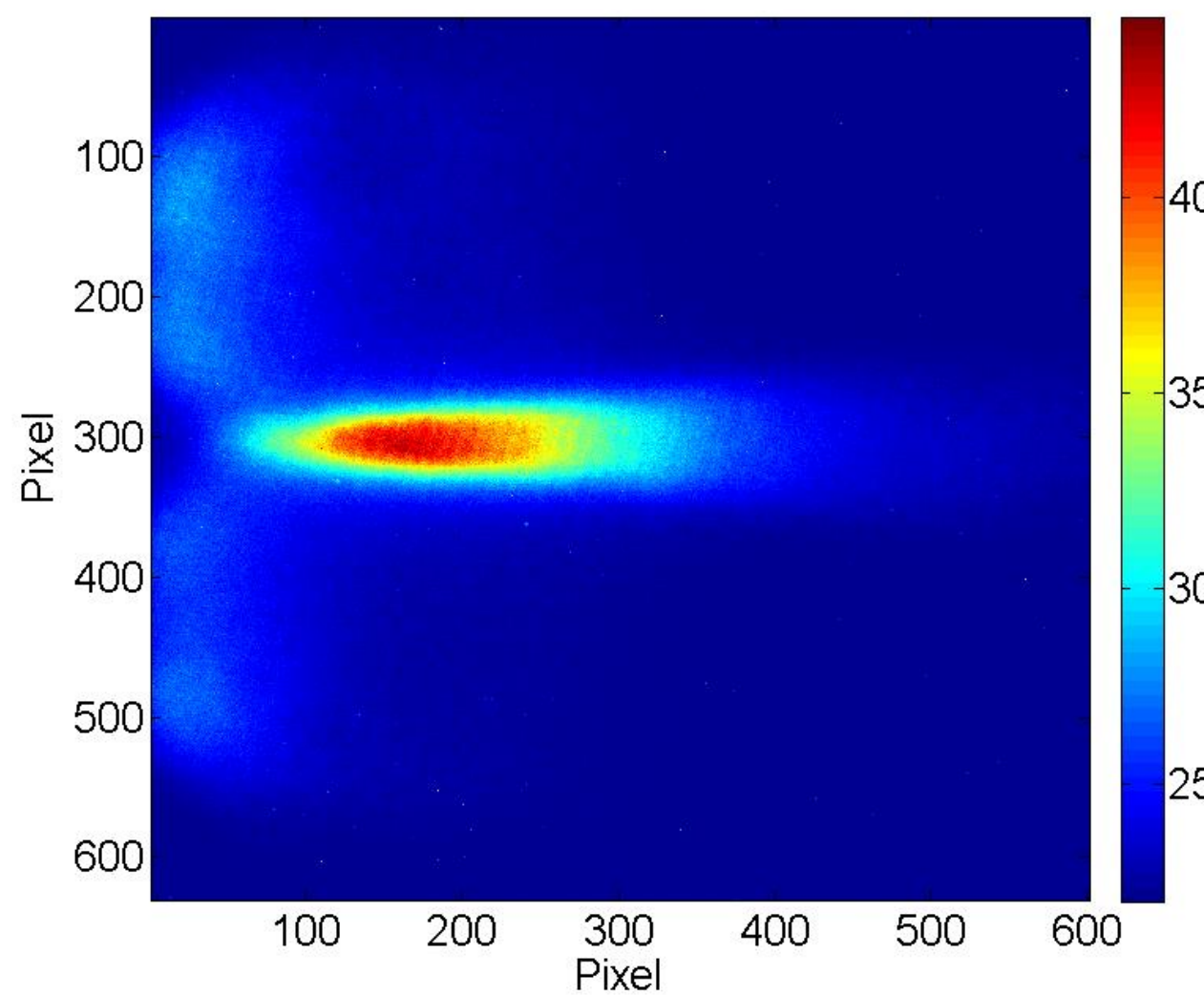


Figure 2. Camera image

Cross section of stagnation layer for length

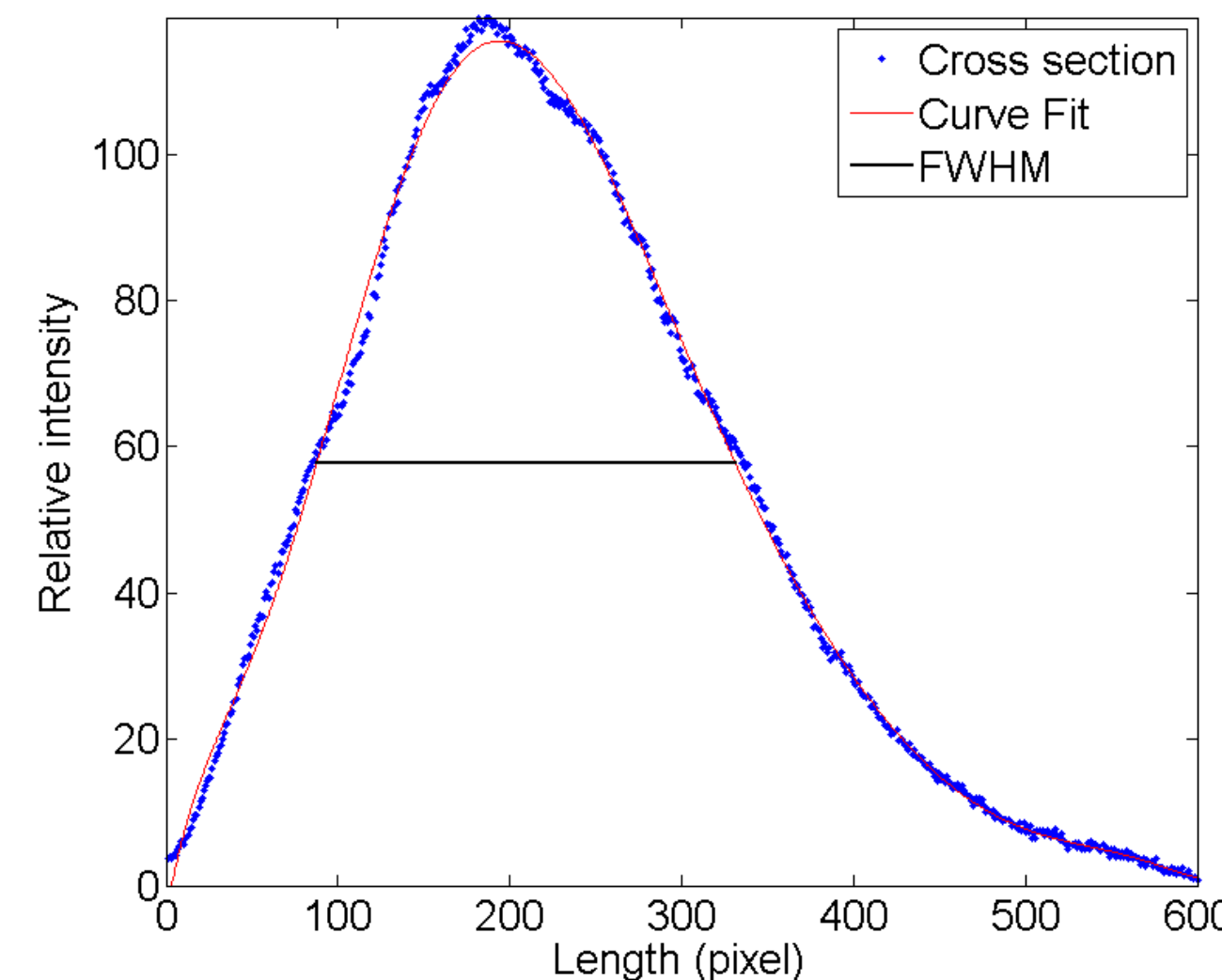


Figure 3. Horizontal cross section

Cross section of stagnation layer for width

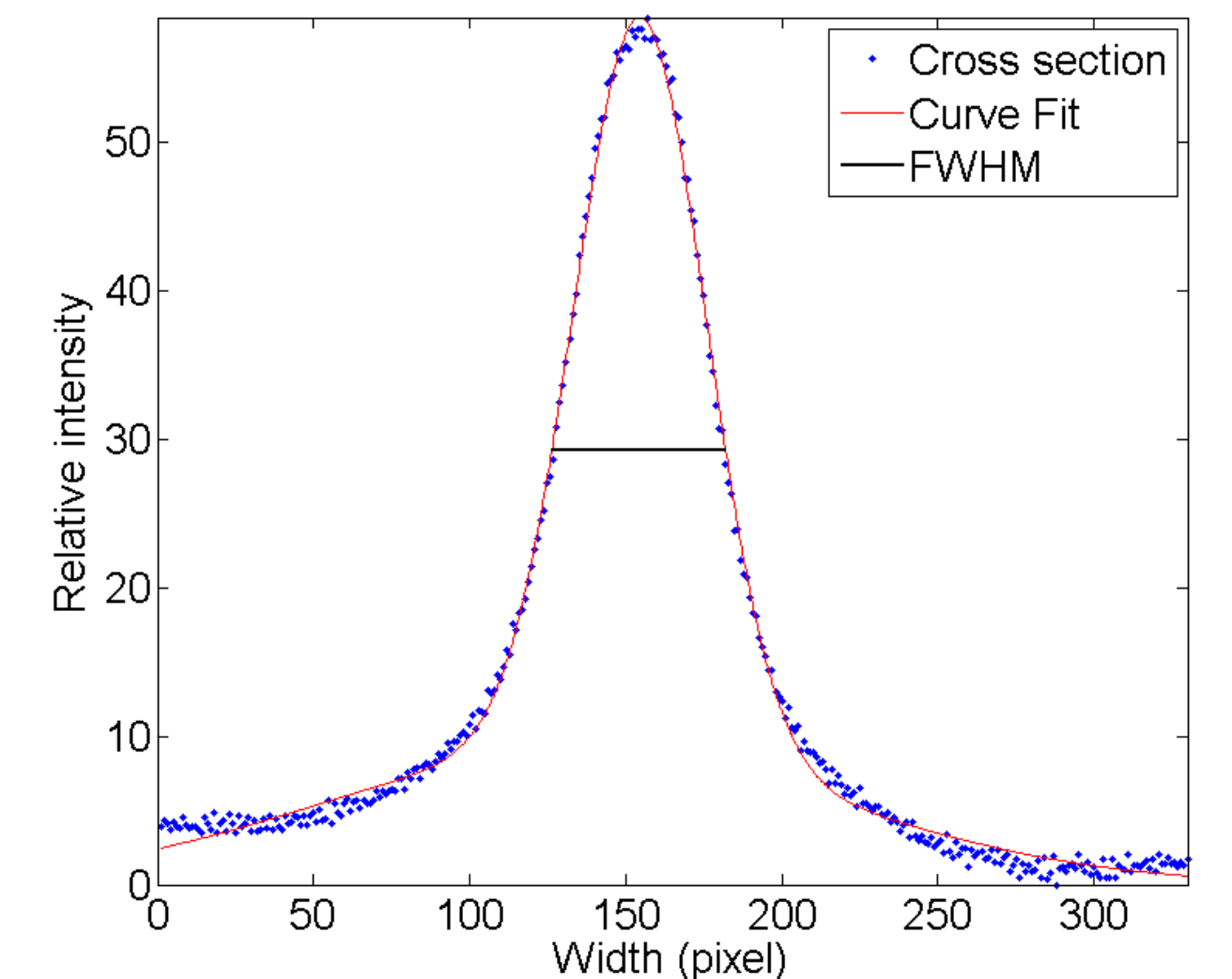


Figure 4. Vertical cross section

Sn stagnation layer length for different lens positions

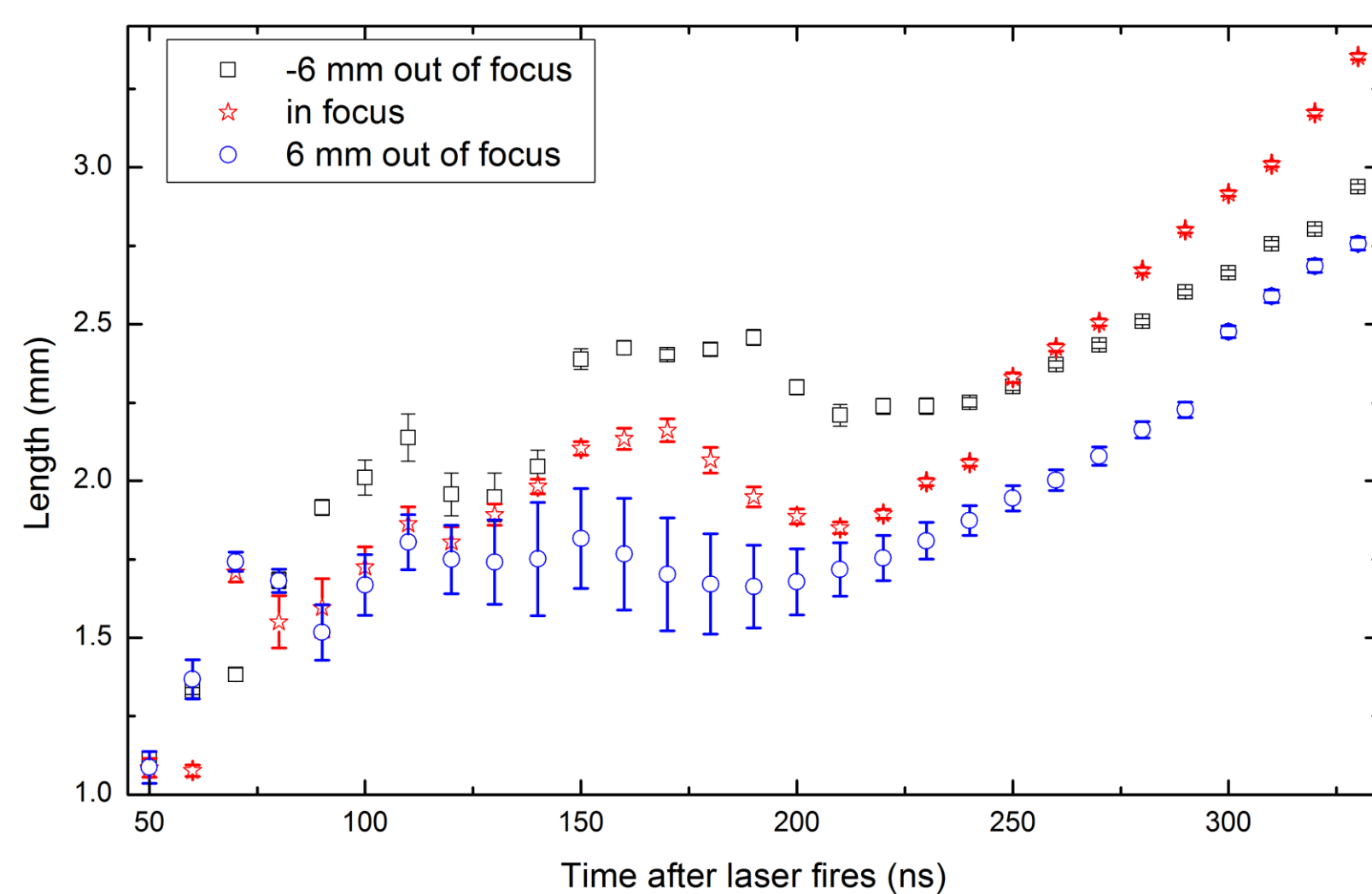


Figure 5. Length of Sn stagnation layer

Sn stagnation layer width for different lens positions

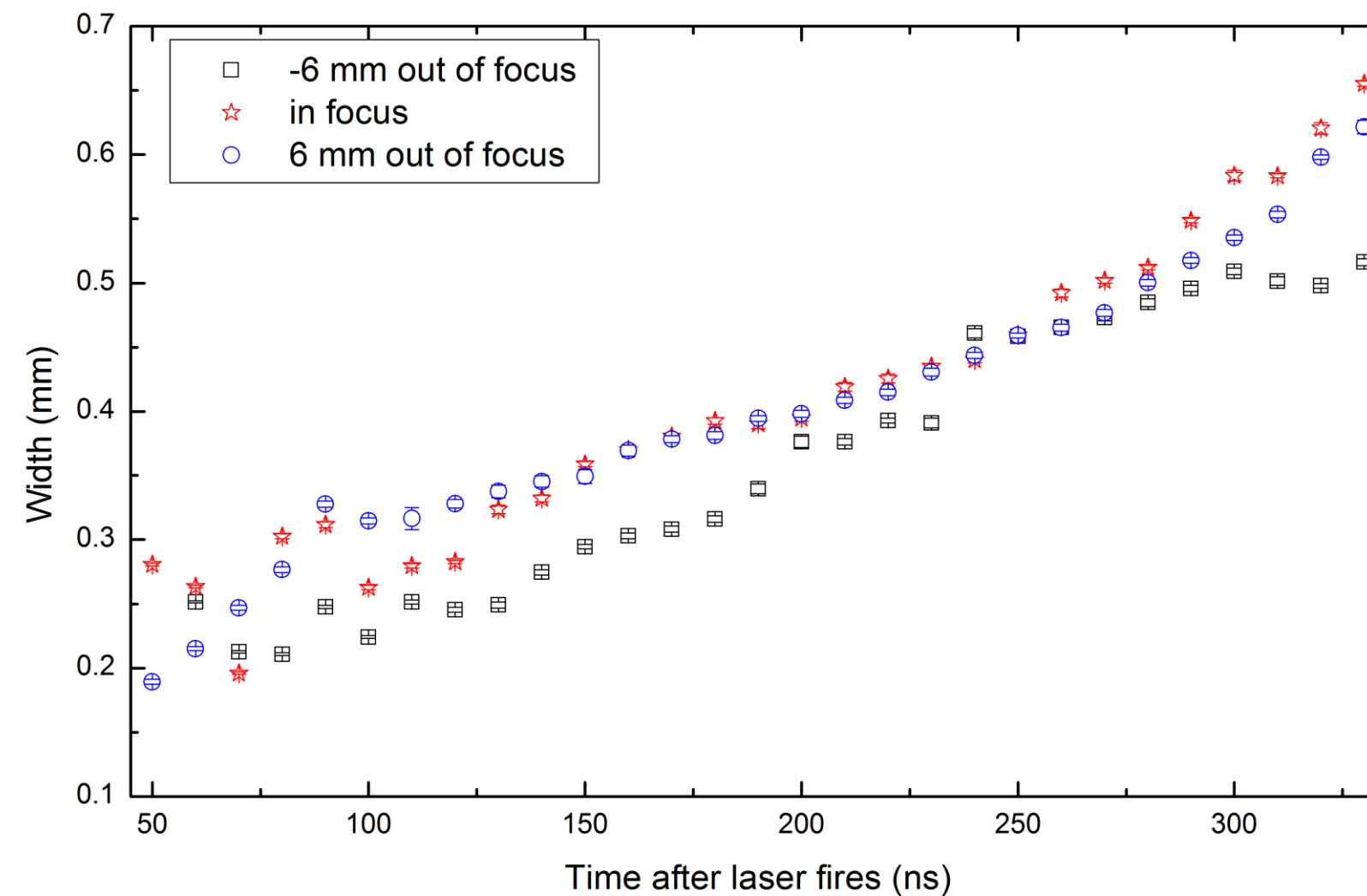


Figure 6. Width of Sn stagnation layer

Sn Stagnation layer length and relative intensity

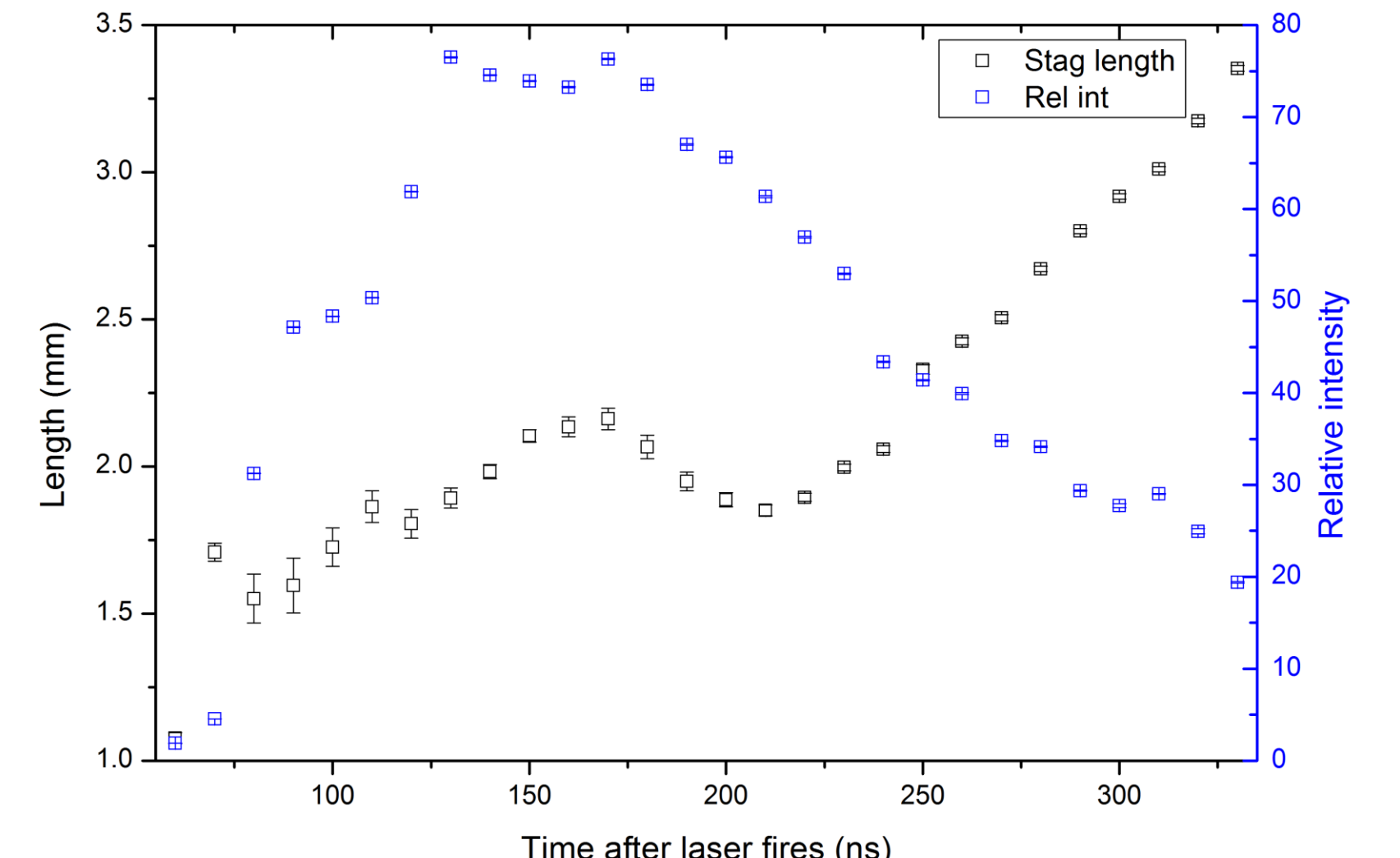


Figure 7. Length and intensity at focus

Stagnation layer length for different elements

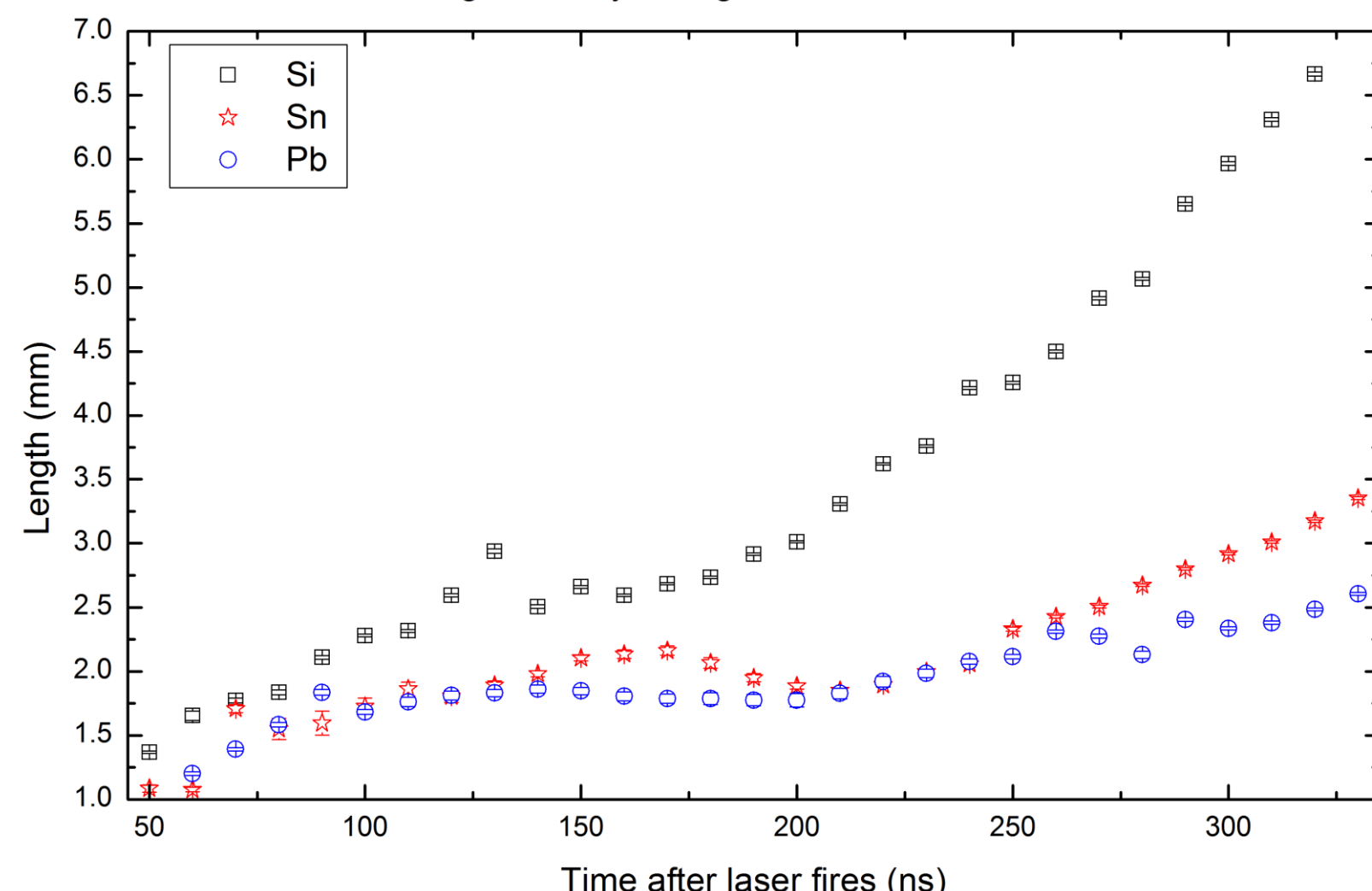


Figure 8. Length of stagnation layer for different elements

Stagnation layer width for different elements

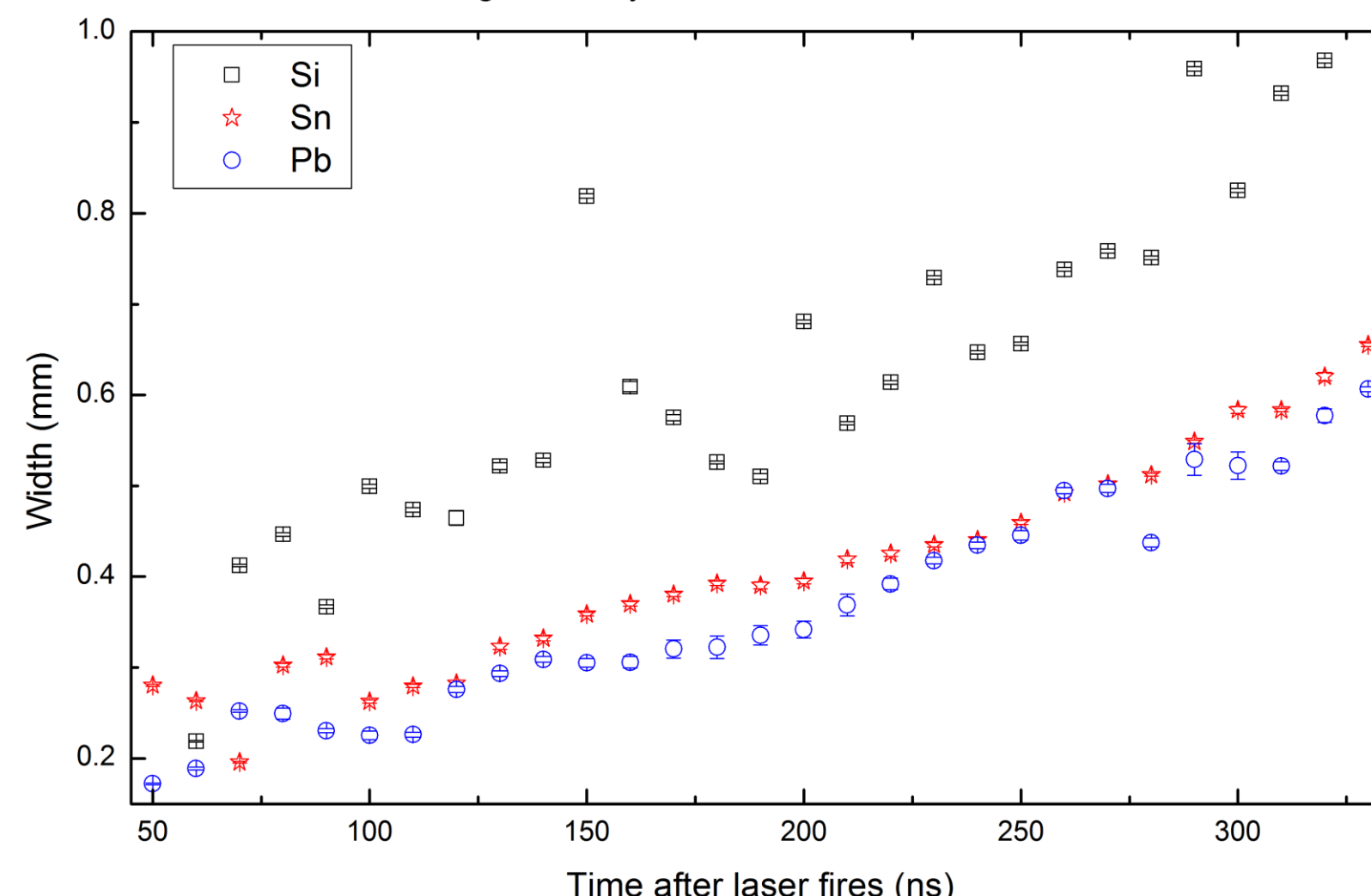


Figure 9. Width of stagnation layer for different elements

## Conclusion

Properties of stagnation layer depend on seed plasma parameters, mainly kinetic energy.

Heavier elements form a longer living stagnation layer from colliding flat target plasmas

There is a time (~170 ns after laser fires) when Sn stagnation layer seems most stable for reheating

## Future work

Further investigate the kinetic energy of plasma from obtained images. Produce a Sn stagnation layer that matches with dimensions of the focus size of a CO<sub>2</sub> laser.

## Acknowledgement

This work was enabled by the Education, Audiovisual and Culture Executive Agency (EACEA) Erasmus Mundus Joint Doctorate Programme Project No. 2012-0033.

## References

[1] T. Cummins, C. O'Gorman, P. Dunne, E. Sokell, G. O'Sullivan, and P. Hayden, *Colliding laser-produced plasmas as targets for laser-generated extreme ultraviolet sources*, Applied Physics Letters, **105** (4), 2014.